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AUTOMATED SYSTEM FOR DIAGNOSING CRANIOCEREBRAL INJURY

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16. Abstract

The article describes a Russian national computing and communication system designed to assist non-specialized physicans in the diagnosis and treatment of craniocerebral injury.

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AUTOMATED SYSTEM FOR DIAGNOSING CRANIOCEREBRAL INJURY

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In the "Main Directions for Development of the USSR National Economy for 1976-1980" further development and improvement in the effective use of automated control systems (ACS) and computers are provided for by successive unification of them into a national system for collection and processing of information for computing, planning, controlling and creating computer centers of collective use. /94**

In recent years the USSR Ministry of Public Health has been intensively developing automated systems for the collection and processing of information, 23 ACS have been made, and 22 information computer centers have been put into operation (V. M. Timonin).

In developing the principles of construction for a model of the public health system for the municipal population V. P. Kaznacheyev et al. in the ACS "Gorod" the function of the first of them, the ACS "Gorzdravh" includes an increase in the effectiveness of health protection for the population due to automation of the activity for control of public health and coordination of all organizations of the city that implement health protection; the function of the second, the ACS "Zdorov'ye," includes an increase in the effectiveness of medical and sanitary servicing of the population. The latter can be attained, on the one hand, with the help of creation

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of automated systems of mass preventive examinations and systems of prediction,[1] and on the other hand--with the help of automated diagnostic systems that guarantee machine diagnostics of a certain circle of diseases. Thus in the A. V. Vishnevskiy Institute of Surgery a remote control diagnostic system has been set up for diagnosis of acute surgical diseases of the heart and organs of the gastrointestinal tract (M. L. Bykhovskiy et al.). The first phase of the automated system for analysis of medical data is operating in the Oncological Scientific Center, the information-retrieval system of medical radiology and radiation therapy in the Institute of Medical Radiology, the information-diagnostic system for surgical treatment of acquired valvular diseases in the A. N. Bakulev Institute of Cardiovascular Surgery, the information-computer system on psychiatry in the V. P. Serbskiy Institute of Forensic Psychiatry, etc.

Craniocerebral injury is one of the diseases for which machine diagnostics is very desirable.

Diagnostics in these cases is urgent since the general state of the patient is extremely serious, and the symptoms that can be studied are insufficient for a confident conclusion. In addition, often the patients are not sent to specialized treatment institutions, where consultation of the neurosurgeon and neuropathologist are provided, but to any treatment institution located near the site of accident. According to the data of I. S. Babchin, despite the growth in neurosurgical treatment network 70-80% of the patients with craniocerebral injury enter nonspecialized institutions where the physicians are faced with a complicated task; its solution without the immediate and qualified consultation is extremely difficult. The interests of the practicing physicians in this respect can be guaranteed by the centers of express diagnostics where the physicians (regardless of their specialty and qualification) can turn by telephone at any time of the day. /95

The first system of such type was set up in 1968 in Prague (P. Nadvornik et al), whereupon the physicans who turned to the computer center received immediately two answers: which of the seven forms of traumatic injury is the most probable in the victim, and which of 15 methods of conservative or surgical treatment is the most efficient. Already in a year physicians not only from Prague but also entire east

[1] Thus, starting in 1971 the information-computer system for prediction of influenza epidemics as been functioning (with center in Leningrad) that is automatically linked to 100 cities in the USSR (Yu. G. Ivannikov et al.).

Czechoslovakia could turn to the center (Navdvornik et al.).

In Leningrad in the Scientific Research Institute of Experimental Medicine of the USSR Academy of Medical Sciences the system of rapid diagnosis for cranio-cerebral injury that gives an answer on the nature and on the localization of the injury was finished in 1973 and it is currently operating. Both the medical and the algorithmic parts of the system are continually being modified and supplemented.

The system is a set that has the following interrelated links.

1. Active algorithms and programs (on punched cards and magnetic tape), their description (according to the requirements of the State Fund of Algorithms and Programs), and instructions for the operator on their use.

The currently active algorithm of diagnostics that is realized in the form of a program in the "Fortran-IV" language for the digital computer "Minsk-32" (A. P. Matveyev et al., 1978a and b) consists of two parts. The first part is a multidimensional scaling of discrete signs according to the data of each class, all of whose objects are represented by their signs in the multidimensional space of the ordinal scales. At this stage for each class of objects with regard for the peculiarities of the distribution of its sampling the space of the ordinal scales of signs is transformed into the space of metric scales in which the Boolean rules of the probability theory acquire a simple algebraic form (I. Pfantsagl'). Evaluation of the ordinal statistics corresponding to the boundaries of the zones for the scale of equal ratios is made from the formulas:

$$\mathrm{KB}(1) = \frac{KS}{a^2},$$

$$\mathrm{KB}(2) = \frac{KS}{a^2},$$

$$\mathrm{KB}(3) = \frac{KS}{a},$$

where a=2.618; KS--number of objects in which the given sign is measured.

The selection of a as the basis for the Fibonacci series guarantees the best statistical properties of the evaluations of the ordinal statistics and the minimum search time for the scale of equal ratios in the work of the algorithm. Then the position code is computed for each object in each class as a measure of its typicalness:

$$PK(K)=PK(K) + 10^{(D(SR(K)-1}; \; K=\overline{1,N},$$

where PK(0)=0; SR(K)--value of scale of equal ratios for sign (K); D--number of decimal digits in number of signs. All the objects of one class are ordered in accordance with the amount of the position code. /96

The ordinal scales of typicalness of the objects are scaled and corrected. At the final stage the scales of equal ratios of typicalness of the objects in the class of data are opened on the ANP (alphanumeric printer) and they are recorded on magnetic tape.

2. Second part--diagnostics and analysis of the information content of the signs in the multidimensional data.

For each class of objects (j) the measure of nontypicalness (M) of the sign (x_{ij}) of the object (i) is evaluated with the help of the following Boolean rule:

$$((\forall_j,\ j\in(\overline{1,NK})),\ ((\forall_i,\ i\in(\overline{1,N})),$$
$$((\forall_k),\ k\in(\overline{1,n})),$$
$$M^k(x_{ij})=\max(\xi_p(x_{ij}^k),\ \xi_N(x_{ij}^k)),$$

where N--number of objects; ξp--scale of equal ratios "pathology"; ξN--scale of equal ratios "normal"; NK--number of classes.

For each case the table is opened making it possible to deduce the answer and reveal which signs were not typical for the given class, which can also be very useful for the physician making the decision.

3. The developed rules of selection, systematization, coding and punching the medical information (in the form of method manuals and instructions) to the physicians by the computer center and to the technician-punch card operators[2]; coded list of symptoms.[3]

4. Medical information collected in the form of a copy from the histories of sickness of the patients with a certain diagnosis and outcome of the disease, coded, punched, is recorded on magnetic tape ("medical storage of the machine," "general

[2]The principles of systematization are described in detail in the monographs of N. I. Moiseyeva (1967, 1972); ordered lists of the neurological symptomatology are also given there.

[3]The coding list of symptoms is given in the monograph of N. I. Moiseyeva and G. D. Luchko.

set"). In order to make access to the system available to any practicing physician information is fed in a random form common for each medical person, without a specialized information chart. The translation of the data into a language accessible to the machine is made by the physicians in the computer center according to the instructions and coded list of symptoms (see point 2). Instructions are given to the physicians, technician-punched card operators and technician-operators for usage of this information.

5. Instructions on the order of reception of information on each incoming patient for the purposes of diagnostics, sequence of the actions in the establishment of a diagnosis; instructions on the order of response to the hospital from which the information came; instructions on the order of registering and storing the incoming and initial documents.

The order of making a current diagnosis: 1) treatment institutions of Leningrad are informed of the possibility of obtaining diagnostic advice in the case of a request by telephone; 2) reception of data by telephone is carried out by the attendant from 09.30 to 17.30 daily on work days. The reception of data was initially implemented by the colleagues of the computer center. Since 1977 the data have been received by physicians working in state hospital No 17, rarely in the computer center. In certain hospitals of the city that have constant communication the attendant colleagues call on designated days and ask whether any new patients have been admitted; 3) the obtained information is recorded by the physician, recorded in a special log and coded according to the code list, containing 128 paired signs; /97 4) information in the form of a digital code is transmitted to the attendant operator of the computer center; 5) the attendant operator punches the data on punched cards, calls from the working magnetic tapes the diagnostic program and the data of the general set, introduces data on the patient who has been admitted for diagnostics, and implements the diagnostic procedure; 6) the diagnostic answer[4] of the machine is reported to the physician who has received and coded the data(personally or by telephone). The diagnostic blank is filed into a package of answers; 7) the physician sends the diagnostic answer to the hospital from which the information

[4]The answer is a report on the most likely diagnosis for the given patient: severe concussion of the brain; contusion of the brain; epidural hematoma; subdural hematoma; combination of cerebral contusion with epidural hematoma and subarachnoid hemorrhage; combination of contusion and subdural hematoma; combination of contusion, subdural hematoma and subarachnoid hemorrhage; intracerebral hematoma; subarachnoid hemorrhage (with light degree of cerebral contusion); massive mixed injury; disruption in cerebral circulation of nontraumatic etiology.

COMPARISON OF RESULTS OF MEDICAL AND MACHINE DIAGNOSTICS OF CRANIOCEREBRAL INJURY

Diagnosed group	Number of patients	Accuracy of determining nature of injury		Accuracy of determining localization of injury			Number of cases of accurate recognition, nature and localization of process
		number of correct answers	number of errors	number of correct answers	number of errors	number of indefinite answers	
Concussion of the brain	11	8/10	3/1	-	-	-	8/10
Contusion of the brain	60*/28	41/28	19/32	9/26	2/2	17/0	5/12
Hematomas (in combination with contusions of the brain)	97	70/87	27/10	64/73	18/24	15/0	59/69
Acute disorder of cerebral circulation	7	2/6	5/1	2/5	0/0	5/2	2/5
Severe mixed injury (combination of contusion with hematomas and disorder in cerebral circulation)	26	19/22	7/4	17/22	4/4	5/0	15/19
Total	201	140/153	61/48	92/126	24/30	42/2	89/105

*In 32 of the 60 cases in the final diagnosis the localization of the process did not figure, therefore the accuracy of the localization of the process is examined for 28 cases.

Note: In the colums of the table the numerator gives the results of medical, and the denominator--machine diagnostics.

came, and makes a notation in the log with indication of the diagnosis and the time of issuing of the answer; 8) at the end of 2-3 days (in certain cases a week) after establishment of the machine diagnosis the physician who made the coding calls the hospital for clarification of the final diagnosis that is entered into the log; 9) notations in the histories of the disease on the obtained machine diagnosis are made by the physicians of the hospital. /98

The time spent for one case of diagnostics is made up of the time necessary for transmission of data from the hospital on telephone and its recording, which is from 5 to 20 min. (depending on the number of symptoms); the time of coding--from 18 to 12 min. (also depending on the number of symptoms found in the patient); time of punching--3-6 min; time of calculating on the machine--5-8 min; time for evaluating the response of the machine and transmission of this answer on the telephone. On the whole the diagnostic response is given in 30-60 min.

Diagnostics of craniocerebral injury was made with the help of the described system in patients under treatment in state hospitals No. 10, 17, 20 and 26 of Leningrad, as well as in the traumatology departments of the First Leningrad Medical Institute and the Leningrad Sanitary-Hygienic Institute. In individual cases answers were given to other hospitals of the city and to the Sestroretskiy hospital. Here the physicians of different hospitals received 252 diagnostic answers. In 25 cases information was transmitted on the patients who did not receive craniocerebral injury or this injury promoted the detection of the concomitant disease (tumor of the brain, tuberculous meningitis, etc.). In order to evaluate the results of the activity of the diagnostic system the table presents a comparison of the medical and machine diagnostics of the craniocerebral injury in 201 patients whose final diagnosis is known from the results of surgery (108 cases, of them in 29 additional results were obtained from pathological-anatomical study), from data of autopsy (28), or after fairly lengthy clinical observation (65).

As is apparent from the table, the machine diagnosis is somewhat more accurate than the physicians'. One should stress that the diagnosis was made on the machine from data of the first examination in the very beginning of the disease, i.e., precisely when the diagnosis is especially complicated.

Usage of the machine does not require from the physician any special knowledge. The use of the automated systems of diagnostics is accessible for any treatment institution.

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